MULTI-STEP SPREAD SPECTRUM COMMUNICATION APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to direct sequence type (DS) spread spectrum (SS) communications systems. More particularly, the invention relates to such a communications systems which employs a novel and simplified encoding and decoding system so as to greatly simplify and economize the construction and operation thereof.

Spread spectrum type communication systems are generally characterized by use of a relatively large transmission bandwidth as compared to the bandwidth of the information to be transmitted. The remaining transmission bandwidth is utilized to accomplish a relatively broad-band encoding arrangement for encoding of the information. Accordingly, in order to recover the information from the transmitted signal, it is necessary to have a corresponding decoder system.

Such systems and techniques are often also known as pseudo-random or pseudo-noise communications systems or techniques. Such communications systems are utilized for such purposes an anti-jamming, or privacy, and/or receiver selection in systems utilizing plural receivers operating on a single carrier frequency.

An example of the latter type of system is one in which information may be selectively transmitted to one or more designated receivers within a multiple receiver communication system. Each of the receivers is assigned a predetermined and different code. The transmitter selectively transmits information recoverable by any of the individual receivers by modulating the transmitted signal with the same code as that assigned to the selected receiver or receivers. Each receiver in turn matches its reference code in phase with the transmitted code to permit demodulation of the transmitted information. In this manner, selected information can be transmitted to a given receiver while preventing recovery of the same information by other receivers in the same communication system.

Conversely, such systems may also be utilized to permit a receiver to select information from among a plurality of transmitters operating on the same carrier frequency, by the same code matching procedure.

While a variety of spread spectrum techniques have been utilized, all are characterized by at least the following two factors: (1) The transmitted bandwidth is much greater than the bandwidth of the information being transmitted; and (b 2) Some signal form or function other than the information being transmitted is additionally utilized to modulate the transmitted signal.

A number of problems have arisen in such spread spectrum systems. For example, since a relatively broad bandwidth is being utilized, interference from spurious signals, noise and the like over a similarly broad band may hinder proper reception, demodulation and decoding of the transmitted signal. Additionally, some means must be provided to keep the code signal generator of the receiver in synchronization with the corresponding code signal generator of the transmitter to assure proper reception and decoding of the desired information. In such instances, synchronizer arrangements are used both to compensate for timing errors between the transmitter and receiver code generators, as well as for changes in signal path distances and the like which may occur due to variations in ionosphere or Doppler velocities.

Moreover, during reception and acquisition of a transmitted signal at a receiver, autocorrelation of the transmitted signal and receiver reference signal often produces unwanted autocorrelation side lobes. The effect of any high degree of correlation between simultaneously transmitted codes and the receiver reference is to increase the false correlation rate of the receiver (that is, the number of false indications of transmitter and receiver reference code phase synchronizations). This in turn causes spurious signal correlations and interferes with the proper decoding and recovery of the desired information.

In an effort to overcome such spurious signal correlations, the codes utilized are generally selected to minimize both cross-correlation levels and auto-correlation side lobes. Such codes may be selected by various methods of signal analysis, such as the so called Gold code, described in the article entitled "Optical Binary Sequences for Spread Spectrum Multiplexing" in the *I.E.E.E. Transactions on Information Theory*, volume IT-13, pages 619–621, dated October 1967.

However, in present day digital communications equipment, such codes are digitally generated, such that code simplification is desirable in order to minimize circuit complexity and cost. That is, relatively complex codes which often use several thousand bits of information for modulation or demodulation require relatively complex and expensive digital circuitry for their generation and processing in both the modulation and demodulation processes necessary for transmission and reception, respectively. Moreover, such large codes require a relatively higher "chip rate" or rate of code generation in order to effectively modulate typical information signal frequencies. However, the effective available chip rate is strongly restricted by the limited frequency characteristics of available RF circuit components and antenna apparatus.

The aforementioned Gold code as well as the so-called syncopated pseudo-noise generation methods utilize more than one pseudo-noise signal or code to increase the code complexity and effective chip rate compatible with existing RF equipment. Advantageously, however, we have discovered a different technique for combining pseudo-noise signals in such a manner as to obtain an apparently greatly increased spectrum of the transmission similar to that obtained with the foregoing methods without increasing the pseudo-noise code length. Moreover, our technique and related system can be configured to prevent unauthorized reception which may occasionally occur even in some of the prior art Gold code or other modulation systems. Such unauthorized reception may occur by use of a high performance synchroscope or other comparable tool at a point relatively close to the transmitter antenna. However, our technique and system makes such unauthorized reception by such tools or other means extremely difficult or even impossible, while yet requiring no increase in the length of the pseudo-noise codes utilized.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The organization and manner of operation of the invention, together with further objects and advantages thereof, may best be understood by refer-